

3D's of gravitational lensing

- Delay
- Deflection
- Distortion

Delay: 0^{th} derivative

$$\tau = \frac{1+z_L}{H_0} \frac{d_L d_S}{d_{LS}} \left[\frac{1}{2} (\vec{\theta} - \vec{\beta})^2 - \psi_{2D}(\vec{\theta}) \right]$$

$$\vec{\theta} = \vec{\theta}_A, \vec{\theta}_B, \vec{\theta}_C, \vec{\theta}_D, \dots$$

Units: $(\text{angle})^2/H_0$

Deflection: 1st derivative

$$\vec{\nabla}\tau = 0$$

$$\vec{\theta} - \vec{\beta} - \vec{\nabla}\psi_{2D} = 0$$

Units: (angle)¹

Distortion: 2nd derivative

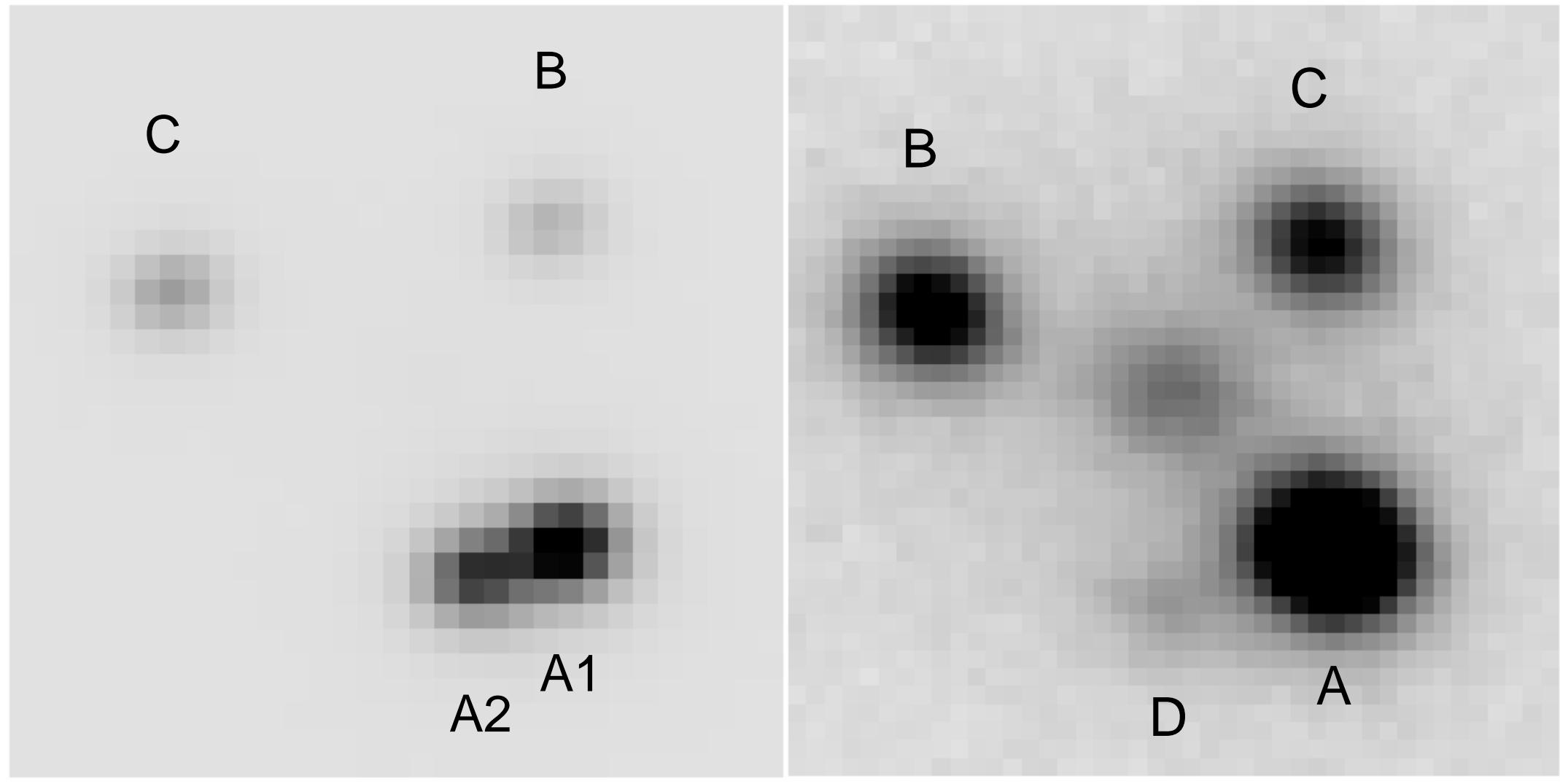
$$\frac{\partial \vec{\beta}}{\partial \vec{\theta}} = \begin{pmatrix} 1 - \frac{\partial^2 \psi}{\partial \theta_x^2} & - \frac{\partial^2 \psi}{\partial \theta_x \partial \theta_y} \\ - \frac{\partial^2 \psi}{\partial \theta_x \partial \theta_y} & 1 - \frac{\partial^2 \psi}{\partial \theta_y^2} \end{pmatrix}$$

$$\left| \frac{\partial \vec{\beta}}{\partial \vec{\theta}} \right| = 1/\mu$$

Units: (angle)⁰

typical quadrupole potential:

$$\psi_{2D} = b\theta[1 + \gamma \cos 2(\phi - \phi_\gamma)]$$



C

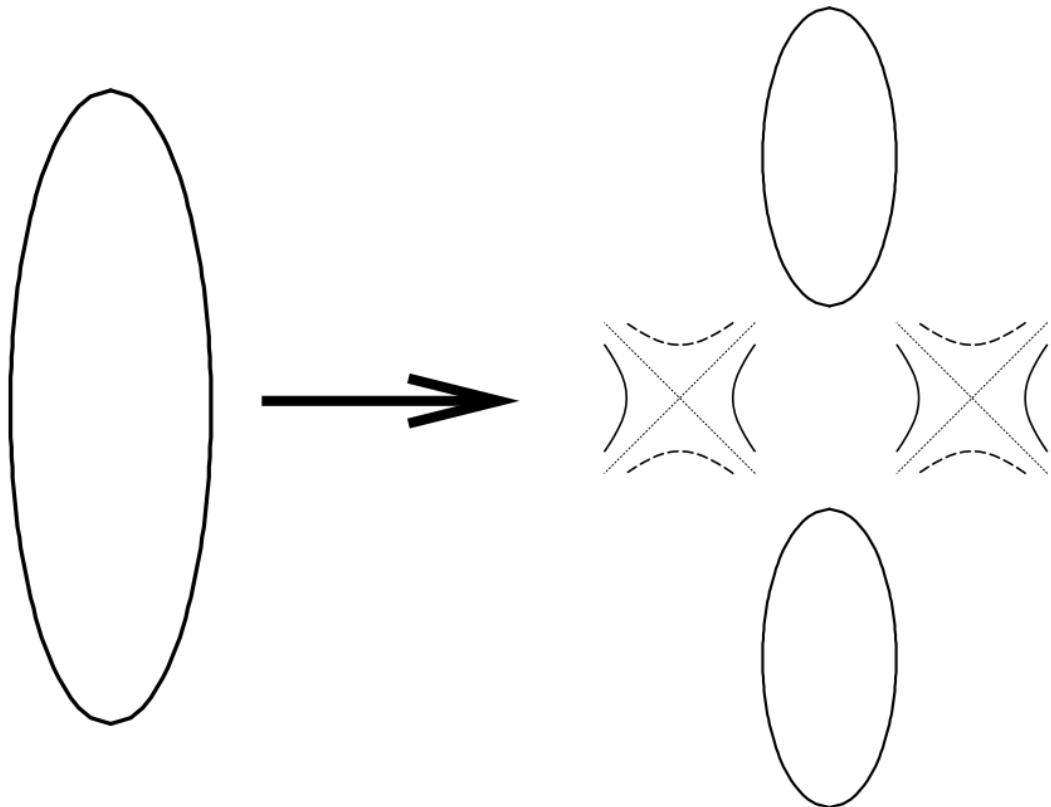
B

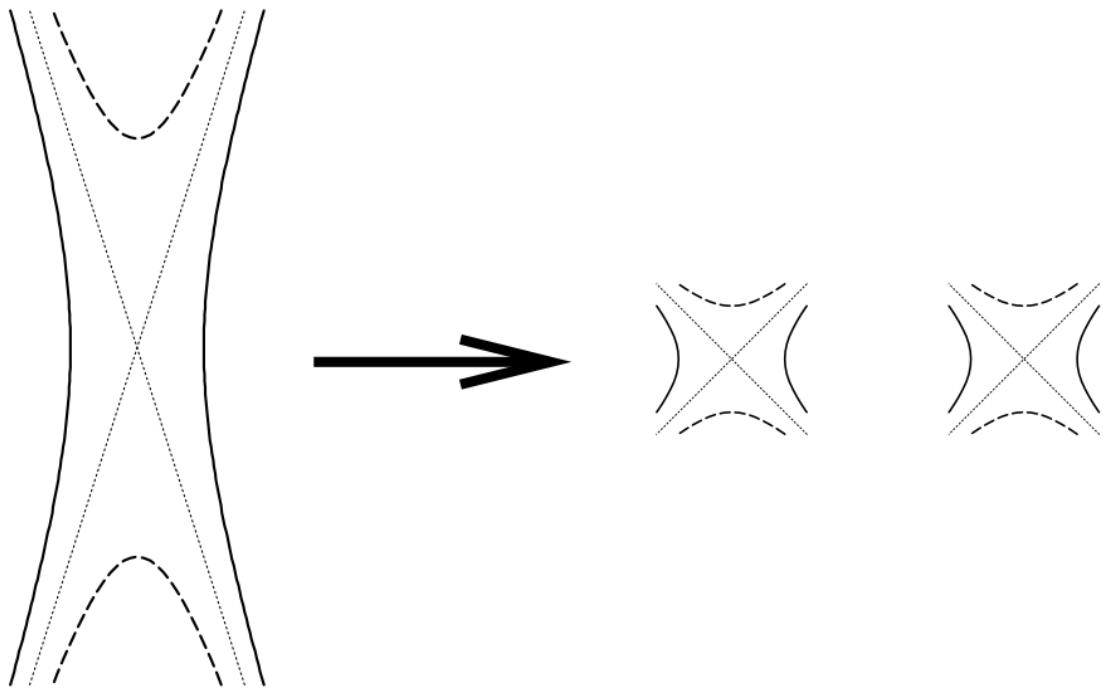
A1
A2

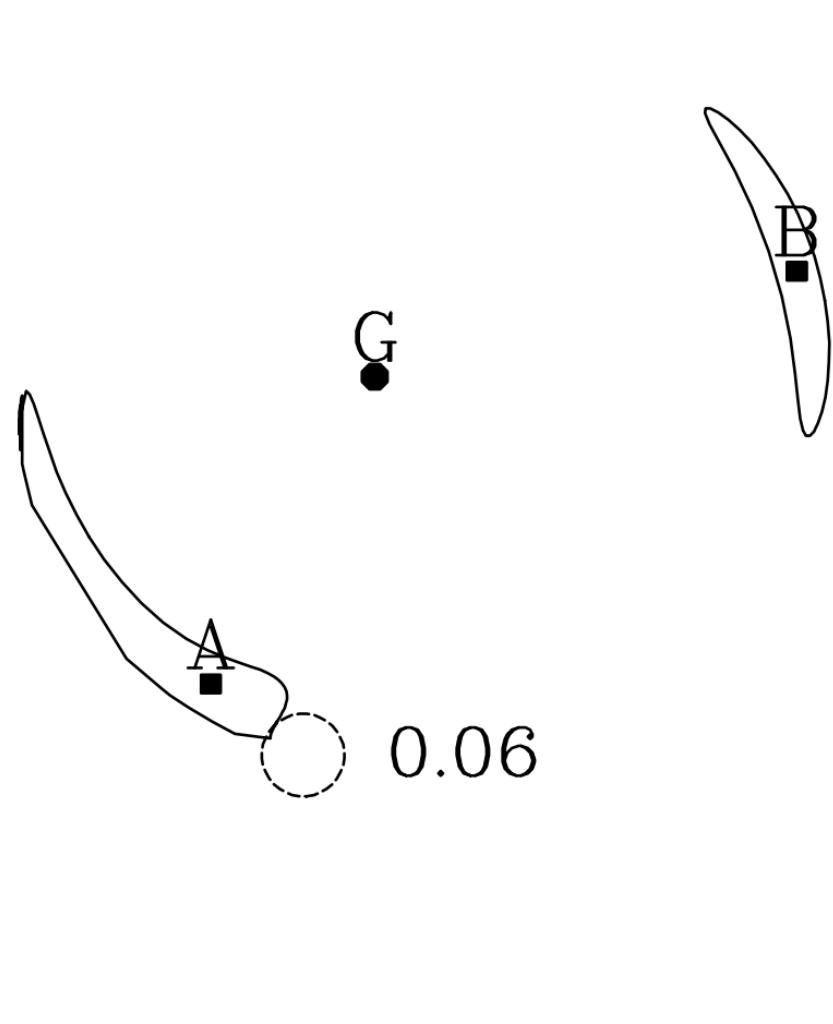
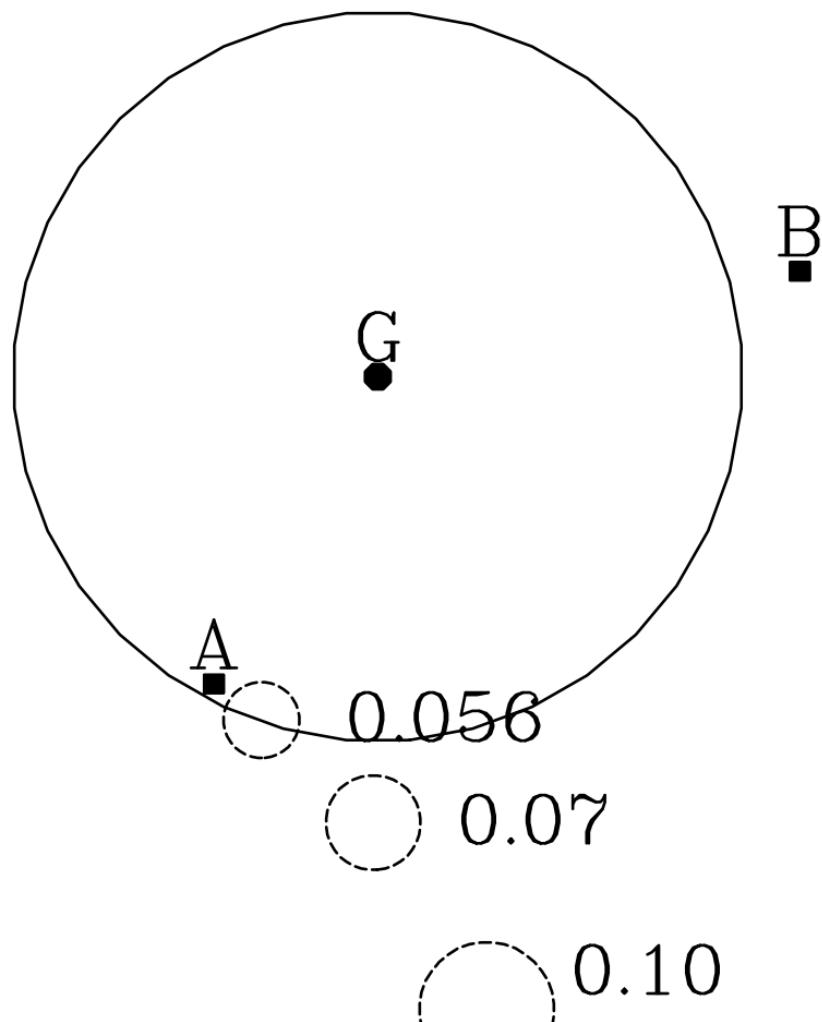
C

B

D
A

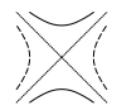


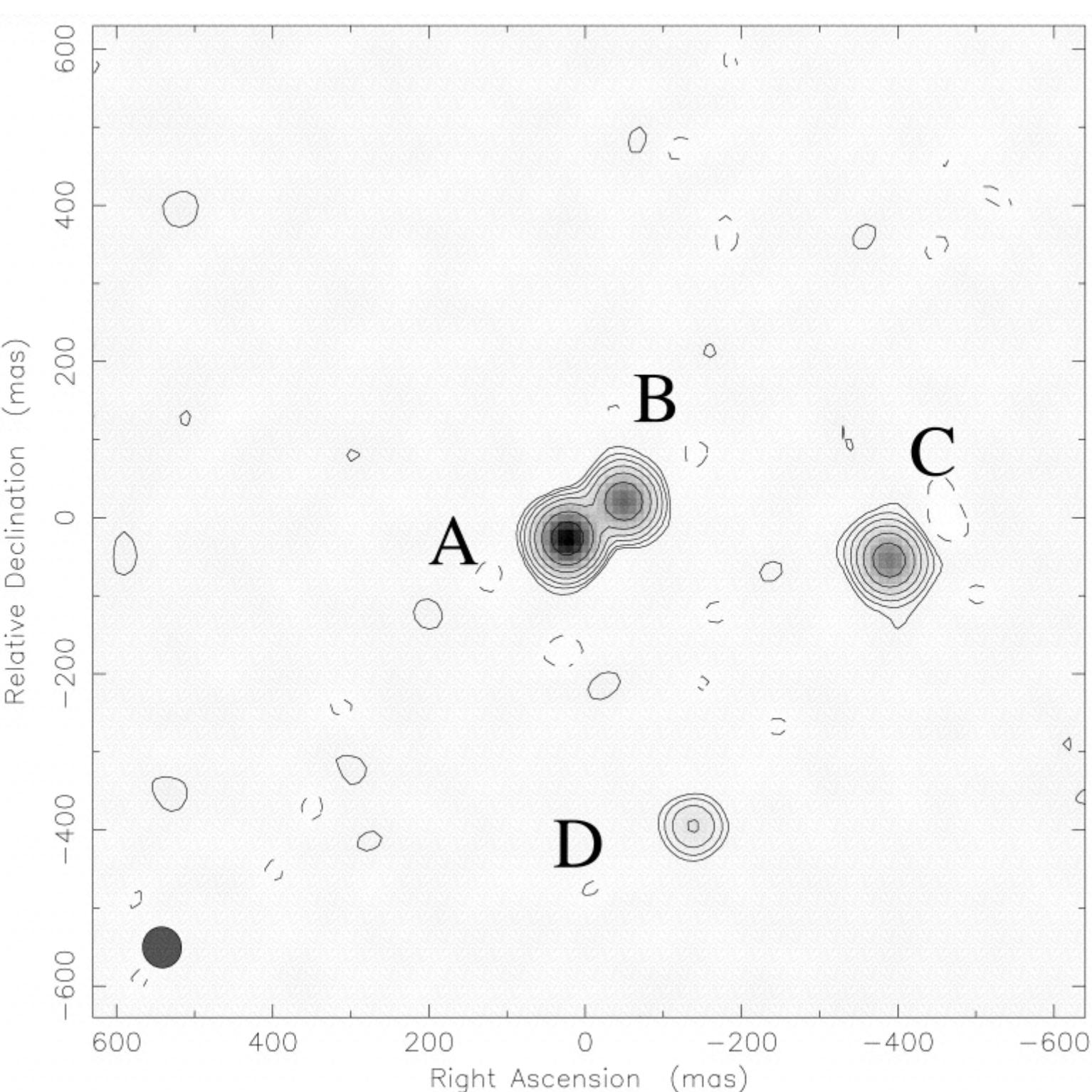




$$\mu_{\text{micro}} = \begin{cases} \frac{1}{4\gamma[(1-\kappa_{\text{tot}})-\gamma]} & \text{○} \\ \frac{1}{4\gamma[(1-\kappa_{\text{tot}})+\gamma]} & \text{×} \end{cases}$$

$$\mu_{\text{milli}} = \begin{cases} \frac{1}{2\gamma[(1-\kappa_{\text{tot}})-\gamma]} \\ \frac{1}{2\gamma[(1-\kappa_{\text{tot}})+\gamma]} \end{cases}$$



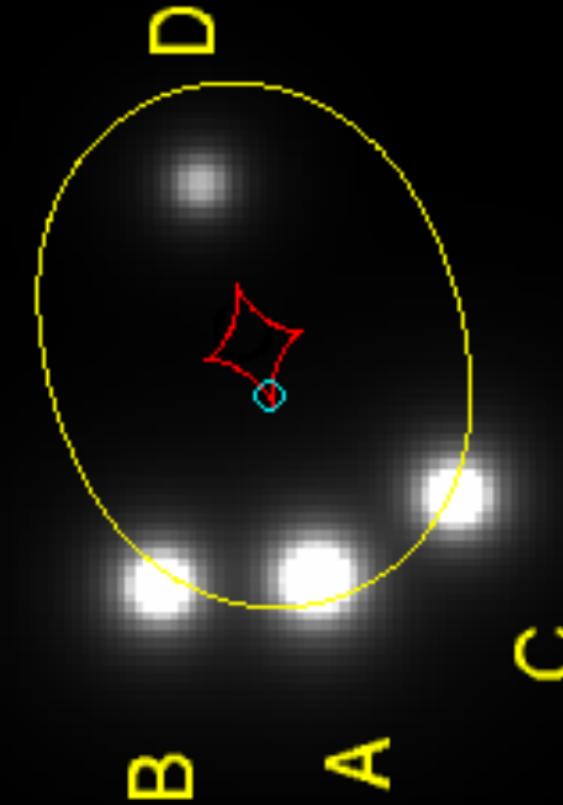


Chandra Image



1"

Magellan Image



A_2

x

x

A_1

x

C

N

B

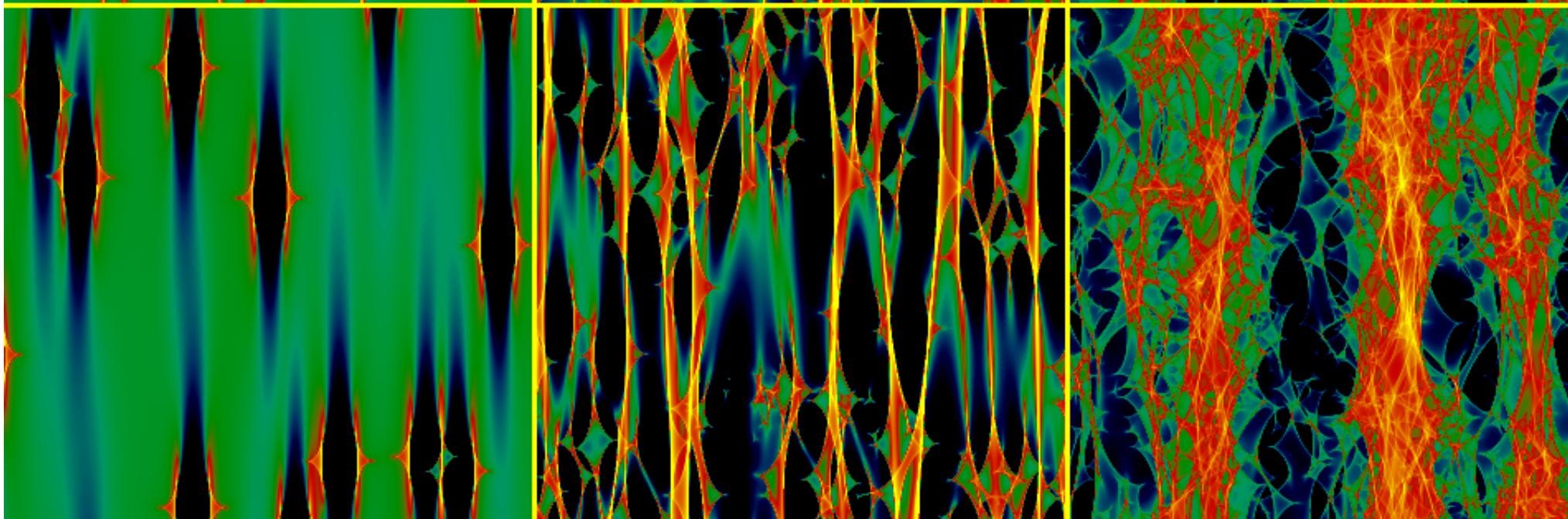
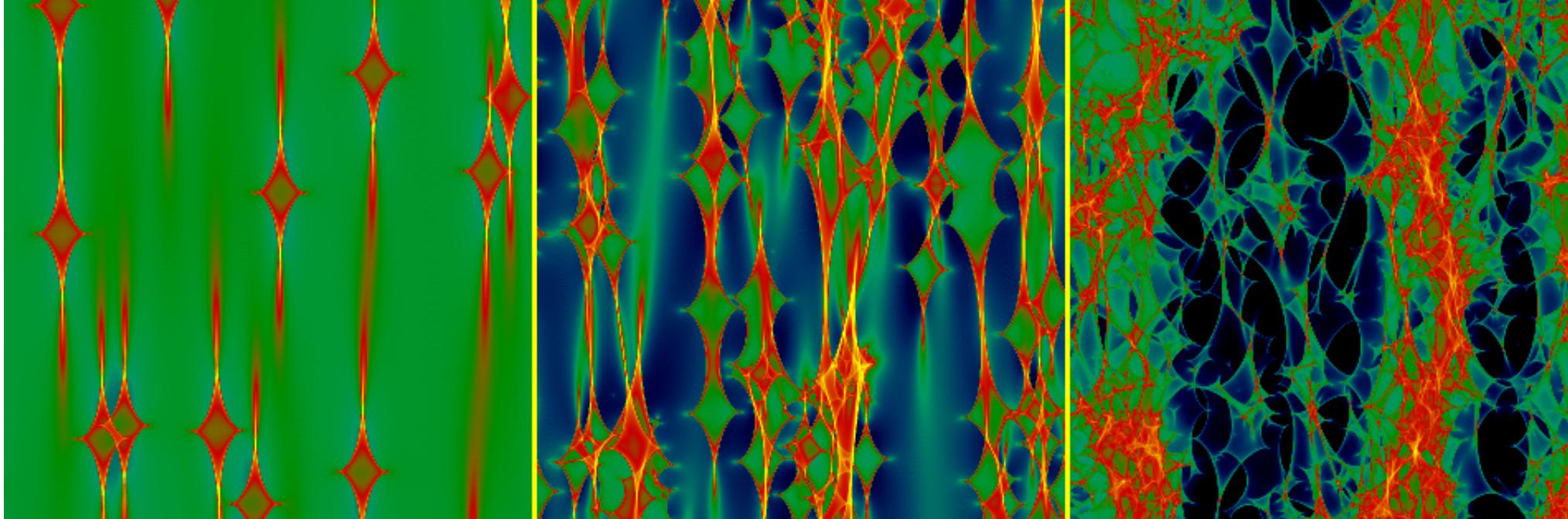
x

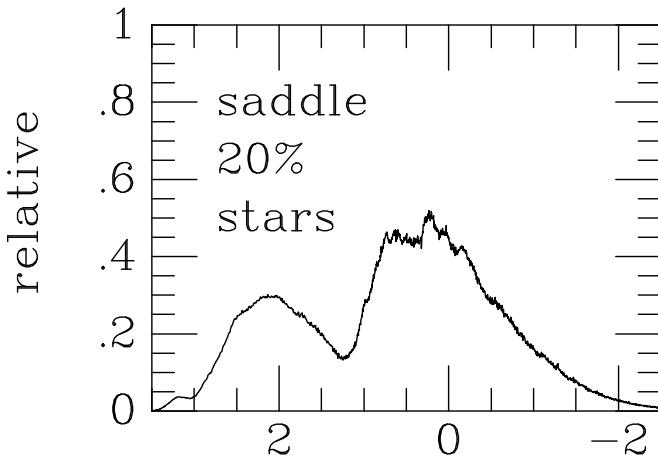
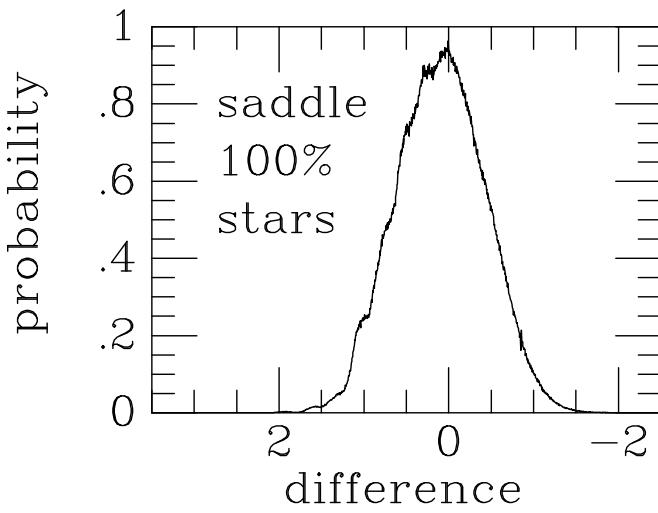
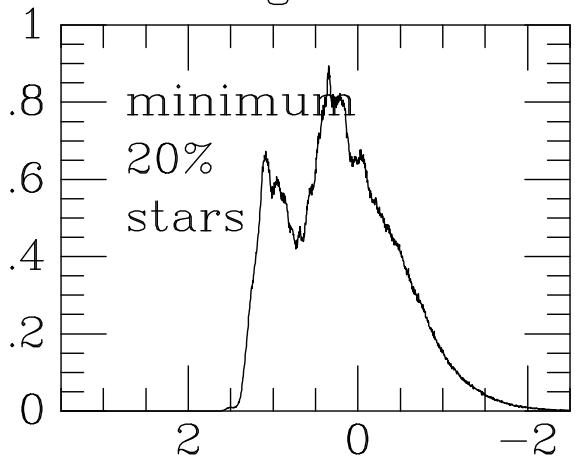
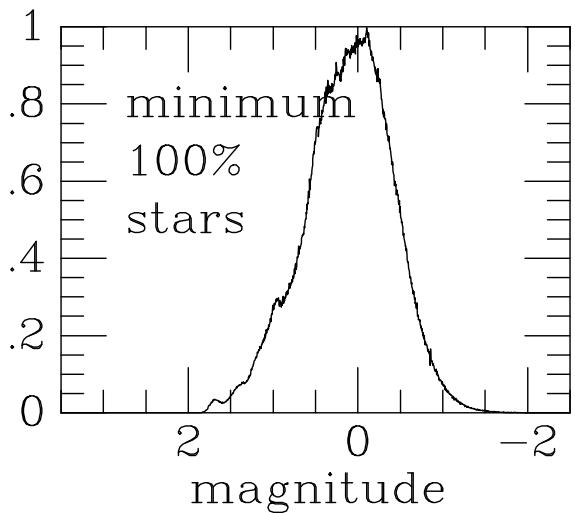
x

x

x

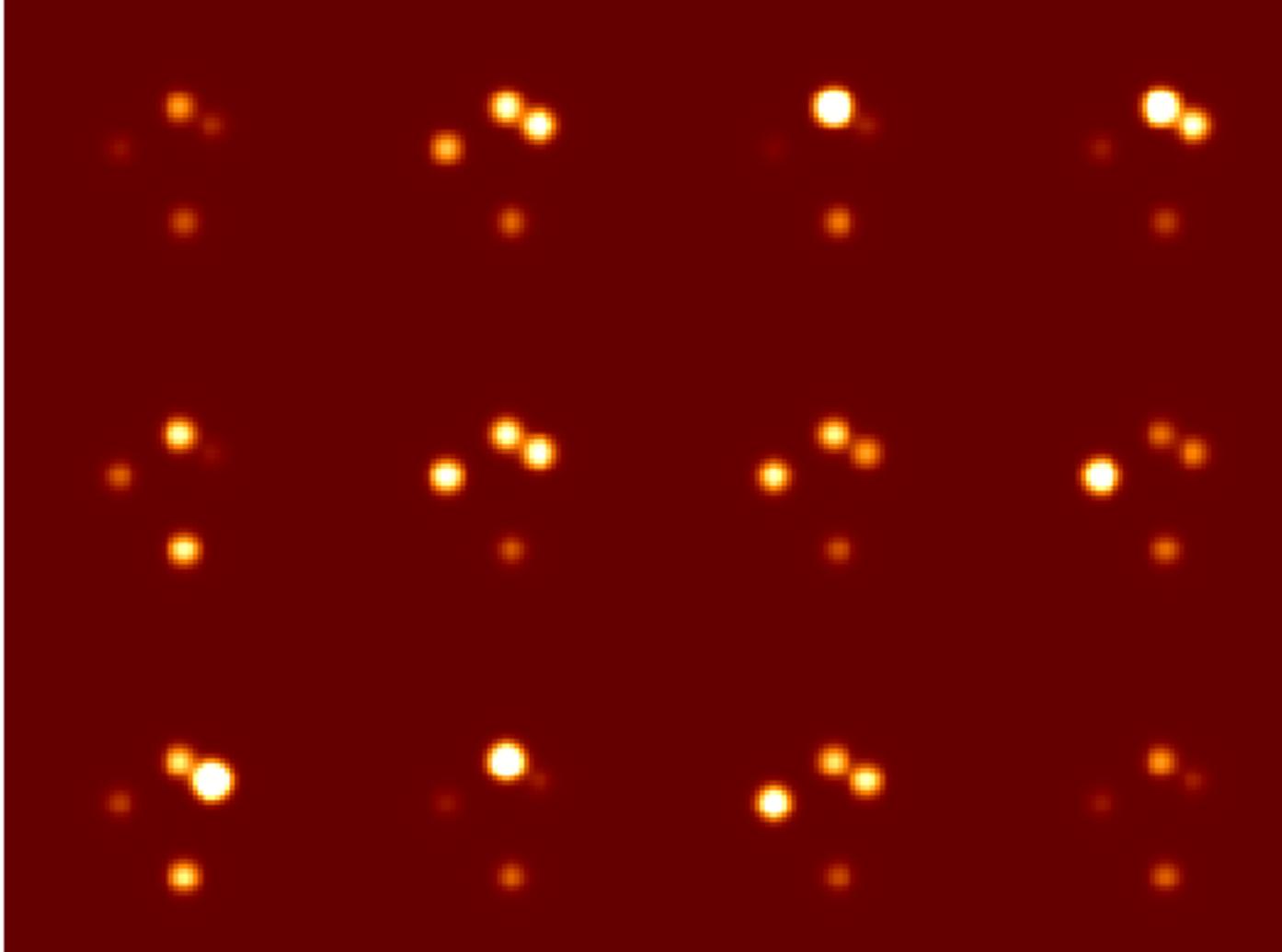
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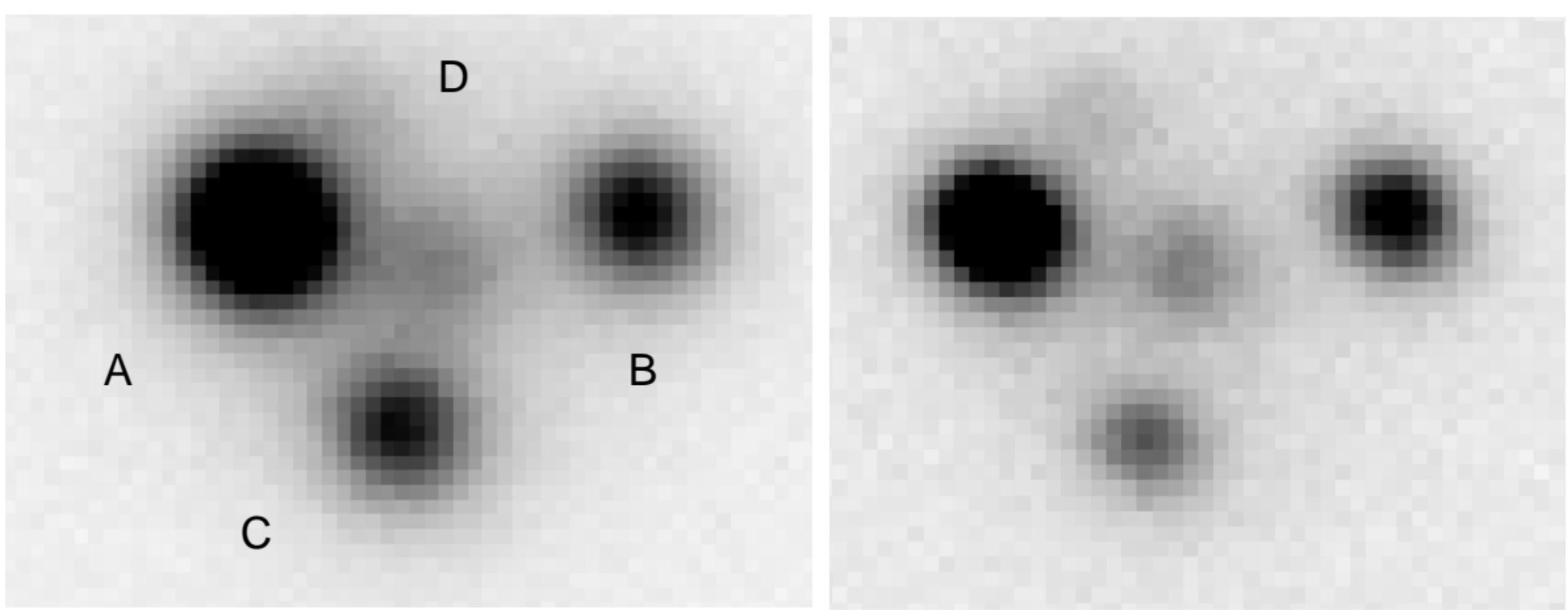




MICRO-LENSING AT UNIT OPTICAL DEPTH: I & II

written,
directed and
produced by
Svetlin Tassev



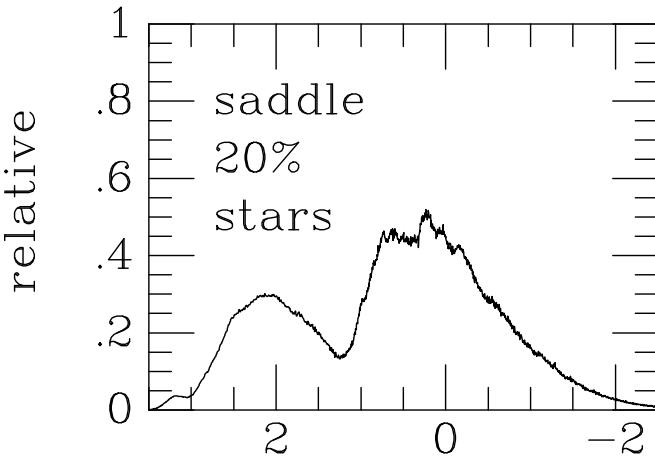
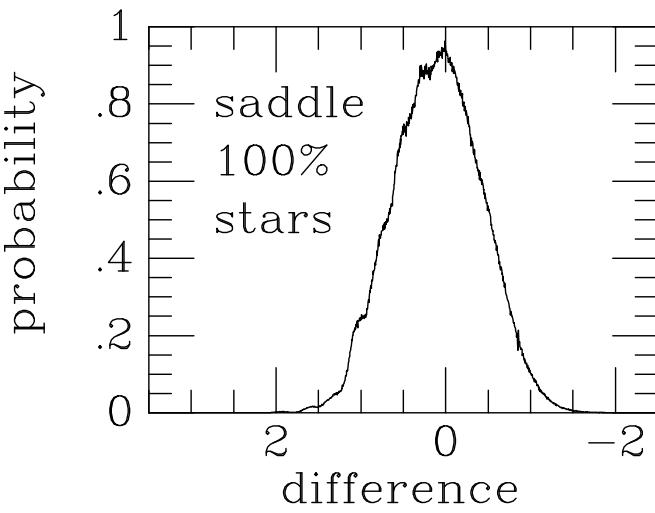
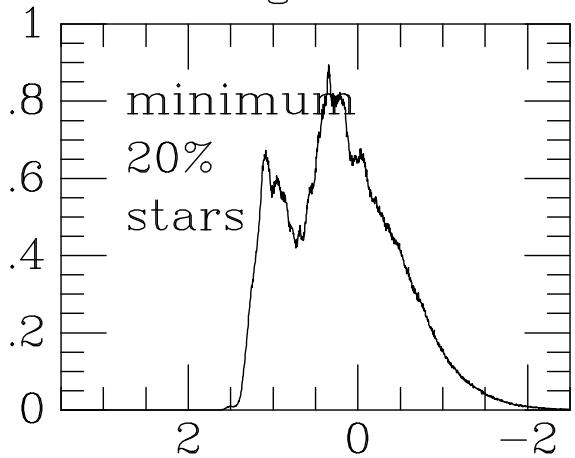
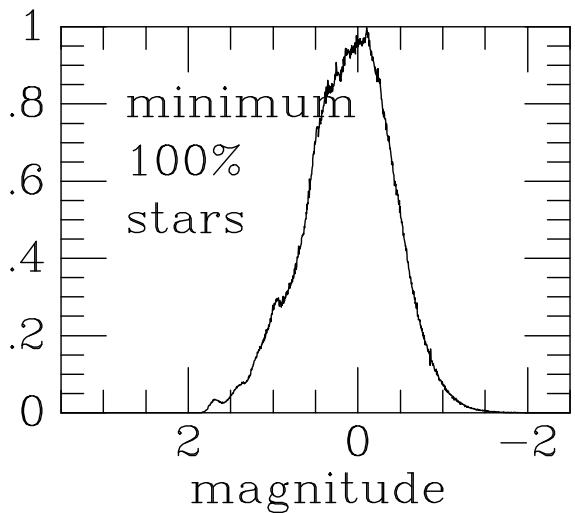


D

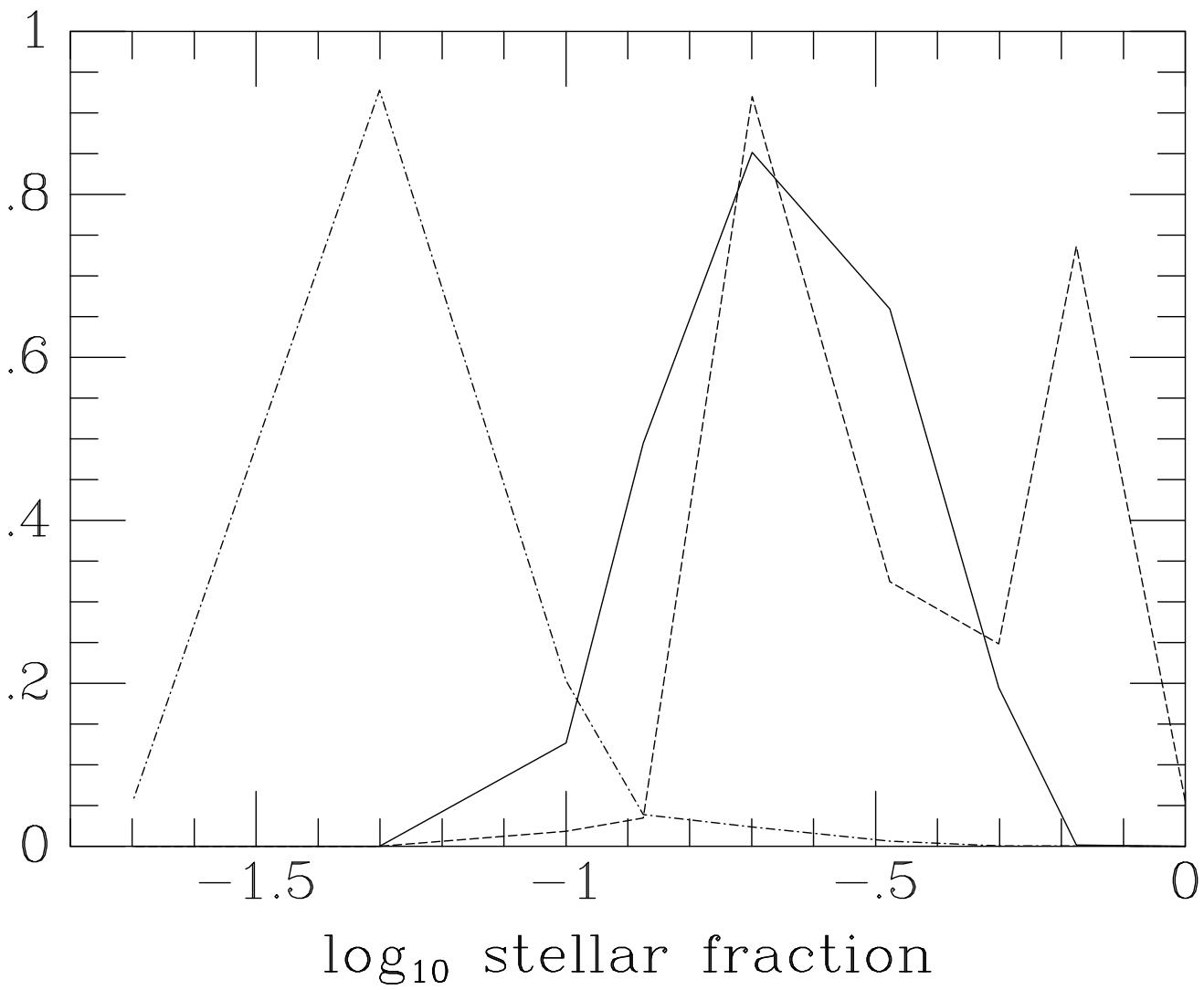
A

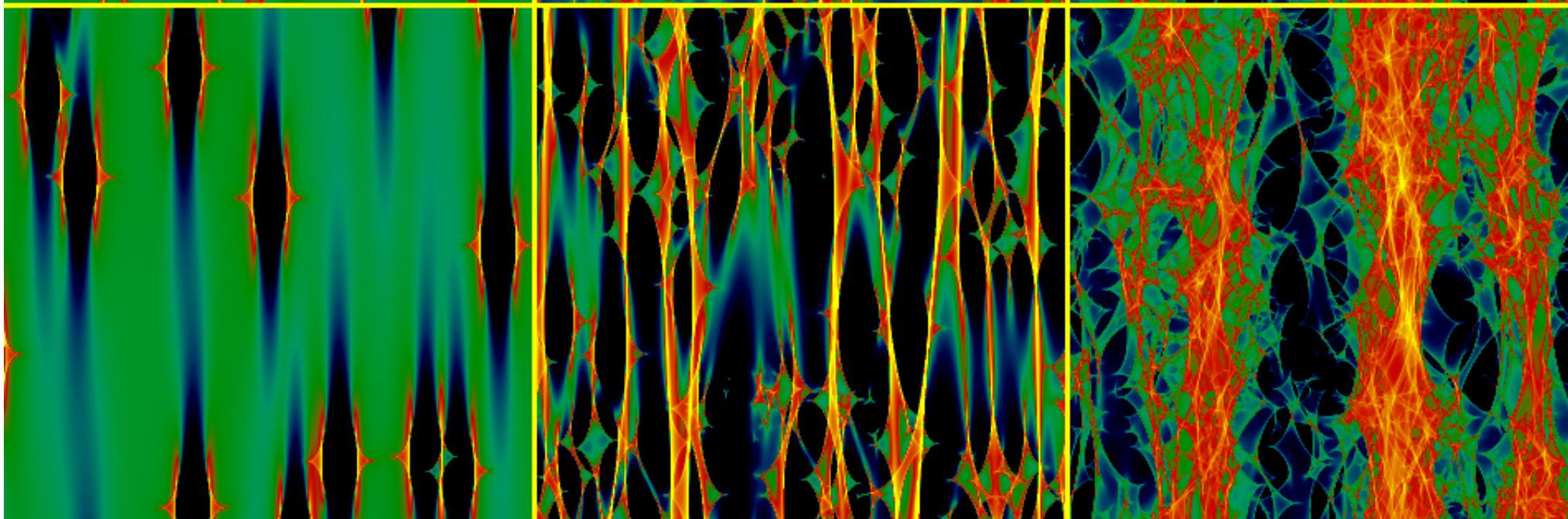
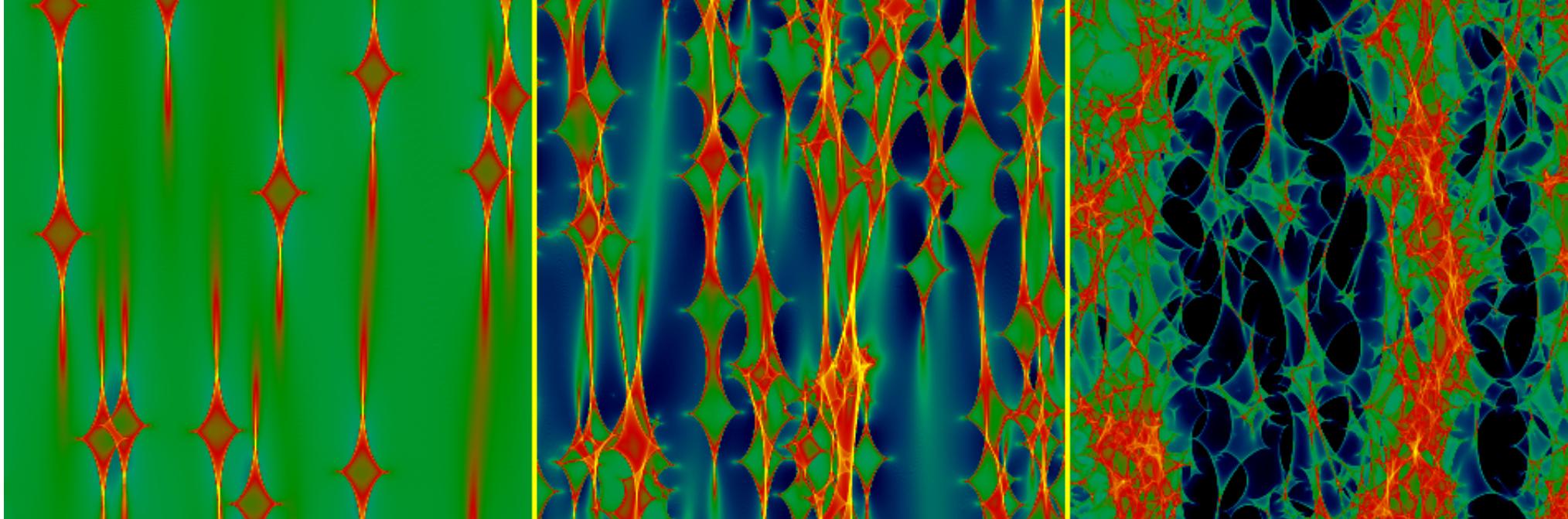
B

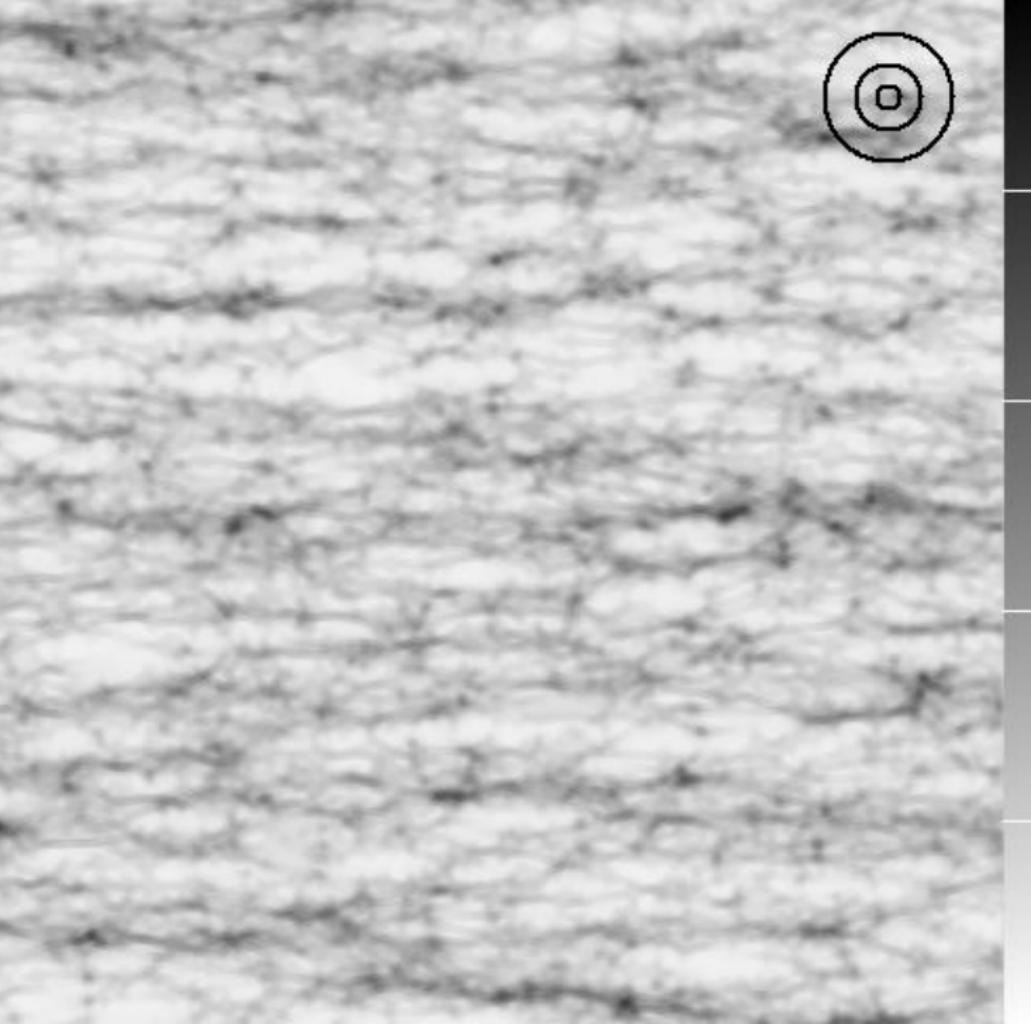
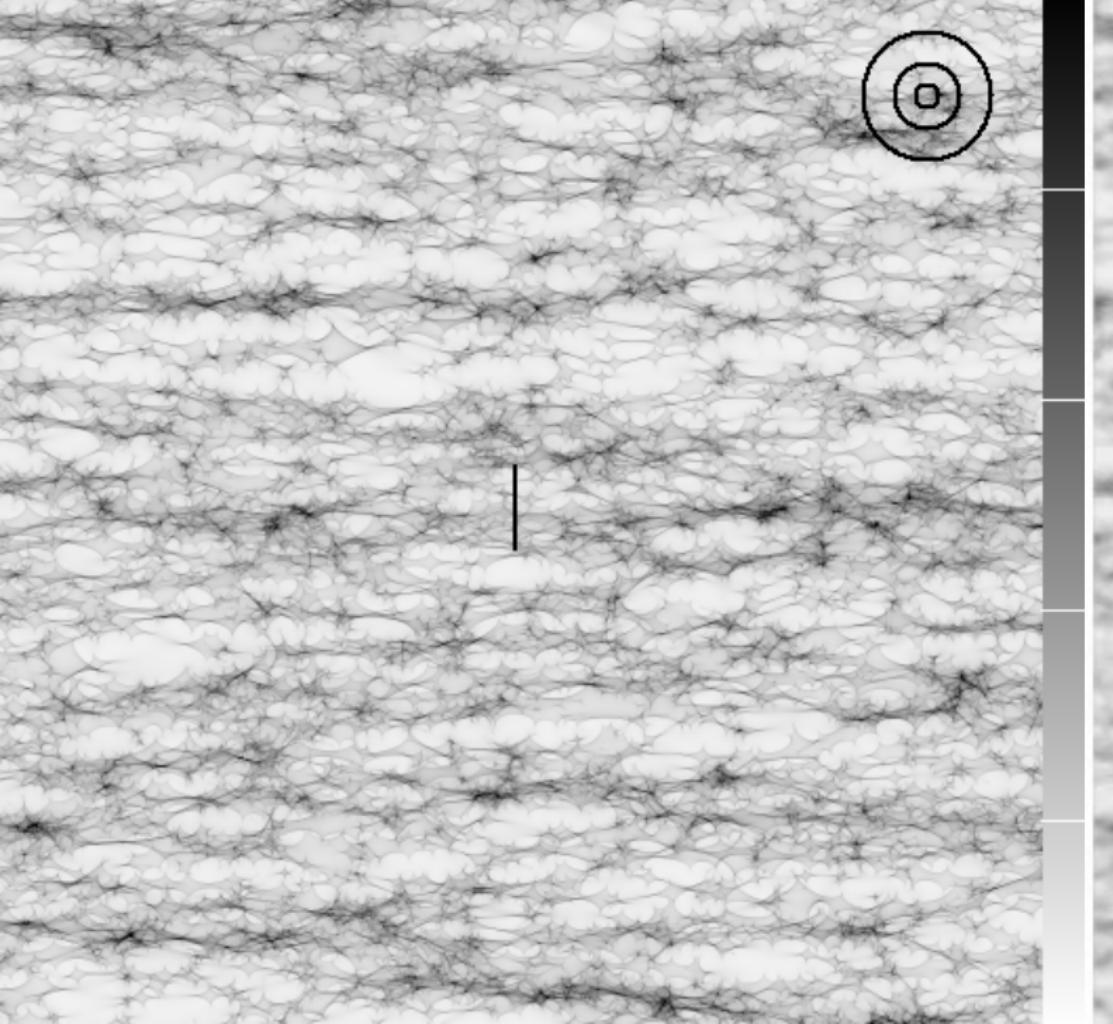
C



relative likelihood







relative likelihood

